

Emerald ash borer, *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), in China: a review and distribution survey

WEI Xia¹, Dick REARDON², WU Yun², SUN Jiang-Hua^{3*}

(1. Forest Protection Institute of Heilongjiang Province, Harbin 150040, China; 2. USDA Forest Service, Forest Health Technology Enterprise Team, Morgantown, WV 26505, USA; 3. State Key Laboratory of Integrated Management of Pest Insects and Rodents, Institute of Zoology, Chinese Academy of Sciences, Beijing 100080, China)

Abstract: Emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), is an exotic forest pest recently discovered in North America, with the infestation centered in Michigan (United States) and Ontario (Canada). A recent pest risk assessment concluded that this new pest could spread throughout the range of ash trees in North America, and pose a serious threat to all 16 species of ash growing in the region. Many ash species are important as timber, ornamental species, and as a source of food for wildlife. This beetle is native to Asia, including China, Japan, Korea, and the Russian Far East. We conducted a literature review on the distribution of this beetle in China and other Asian countries, and preliminary field surveys on its distribution and damage in the northeastern provinces of China. These reviews revealed that this beetle is present in Heilongjiang, Liaoning and Jilin provinces. EAB has also been reported in Tianjin city, Shandong and Hebei provinces, and Xinjiang and Inner Mongolia autonomous regions in China, but its distribution is not uniform, occurring mainly on a stand-by-stand basis. Information on biology and ecology of this beetle is very limited. Several ash species in the genus *Fraxinus* in China were attacked.

Key words: Emerald ash borer; *Agrilus planipennis*; *Fraxinus* spp.; distribution; survey; exotic pest

1 Introduction

Emerald ash borer (EAB) (Pl. I : 1), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), is an exotic forest pest recently discovered in North America, with the infestation centered in Michigan (United States) and Ontario (Canada). It was first discovered in May and June, 2002, in ash trees (*Fraxinus* spp.) in southeastern Michigan, and its exotic pest status was confirmed in July. Later, it was reported (but not established) in Oregon (United States) and Ontario (Canada) (Haack *et al.*, 2002). It was suspected that EAB first arrived in North America more than five years ago (McCullough and Roberts, 2002).

EAB is native to China (mostly in northeastern area, though it has also been reported in Tianjin city, Shandong and Hebei provinces, and Xinjiang and Inner Mongolia autonomous regions), Japan, Korea, and the Russian Far East (Yu, 1992). Formerly, the beetle was named as *Agrilus marcopoli* Obenberger in China**. Information on EAB biology is scarce in China and the rest of its Asian range. Several species of ash are reported as hosts for EAB in China (Yu, 1992). In Michigan and Ontario, EAB has been found on several

species of ash, including *F. americana*, *F. nigra*, and *F. pennsylvanica*. There are 16 species of ash throughout much of eastern North America, and most of them are important as timber, ornamental tree species, and as a source of food for wildlife (Little, 1979). A pest risk assessment recently completed by the Canadian Food Inspection Agency (Dobesberger, 2002) concluded that EAB could spread throughout the range of ash trees in North America, and cause considerable economic and ecological damage. The origin and pathway of North American EAB is still unknown. Thus, a vigorous research, development and application program has been immediately initiated in the United States and Canada. As a result, a cooperative effort between the USDA Forest Service and Heilongjiang Forest Protection Institute, and the Institute of Zoology, Chinese Academy of Sciences, was set up within the overall program to provide preliminary data on its pest status and distribution in China.

2 Identification and Morphology

Adults are larger and a brighter green than any of the native North American species of *Agrilus* (Pl. I : 1). The slender, elongate adults are 7.5 to 13.5 mm

* 通讯作者 Author for correspondence, E-mail: sunjh@panda.ioz.ac.cn

** There are 106 species in the genus *Agrilus* worldwide, with 70 species in Russia, 23 in China, one in Australia, and 12 in North America (Prof. Fang San-Yang, pers. comm.)

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long, and females are larger than males. The adult body is brassy or golden green overall, with darker, metallic, emerald green wing covers or elytra. The top of the abdomen under the elytra is metallic coppery red (seen only when the wings are spread). The prothorax, to which the first pair of legs is attached, is slightly wider than the head but the same width as the base of the elytra. The back edges of the covering on the prothorax are sinuate or wavy, and the top is sculptured with tiny, transverse wavy ridges. The surfaces of the elytra are granularly roughened. Tips of the elytra are rounded with small teeth along the edge.

Larvae reach a length of 26 to 32 mm, and are cream-colored and dorso-ventrally flattened (Pl. I : 2). The brown head is mostly retracted into the prothorax and only the mouthparts are visible externally. The 10-segmented abdomen has a pair of brown, pincerlike appendages on the last segment.

3 Biology of Emerald Ash Borer

Emerald ash borer was first reported and studied by Professor Yu Cheng-Ming at the Northeast Forestry University in Harbin, China. His work, *Preliminary Study on EAB in Harbin* was published as an internal university report in 1964. In the report, he discussed the biology, ecology, and control of the beetle. However, we could not obtain a copy of this report due to the relocation of the university during the Cultural Revolution and the loss of many library holdings. In 2003, we visited Prof. Yu several times to discuss EAB and his findings (Prof. Yu did not keep a copy of the report in his personal collection). He told us that EAB has one generation in two years, and mainly attacks *Fraxinus americana* L., a tree species introduced from the United States, and that EAB damage was so severe in a 10-year-old *F. americana* plantation at the Northeast Forestry University Experimental Forest that the entire plantation was removed. The EAB section in the book *Forest Insects of China* (Yu, 1992) was based on Prof. Yu's work.

Professor LIU Yi-Guo of the Shenyang Institute of Horticulture also studied EAB during 1963–1965, and his work covered biology, ecology, and control, including biological control. In Shenyang of Liaoning Province, this beetle has one generation per year, and only attacks *F. americana*. Prof. Liu wrote a paper, *A study on EAB in Shenyang* (1966), as an internal report.

EAB was first reported in Tianjin city in 1982 on *F. velutina* Torr., and spread at a rate of 1.1 km per year. During 1989–1991, efforts were directed to survey and control the pest, but eventually, all infested trees were cut down: a huge loss of ornamental trees in the city. Mr. Liu Hai-Qing wrote a report on this

outbreak and its control, which was published in *Agricultural and Forestry Science and Technology of Tianjin* in 1996 (Liu *et al.*, 1996).

In 1993, *Fraxinus velutina* was planted at the Guangang District of Tianjin, and severe damage by EAB was found in 1998. A study on the life history, natural enemies, and control of EAB was conducted during 1998–2002 (Liu and Liu, 2002). EAB adults appeared from early May until mid-June, required little supplementary feeding, and required only a few days before mating and ovipositing. Oviposition occurs generally from late May through late June, and some adults were found to oviposit as early as May 10. Eggs were laid separately. The first instar larvae hatched 10 to 15 days after oviposition. Newly hatched larvae feed under the phloem. Late instar larvae appear around September 20 and overwinter under the xylem.

During the course of this work, a braconid parasitoid, *Spathius* sp. was found. This parasitoid has three to four overlapping generations per year in the Guangang District of Tianjin, with the first generation in late June and the second generation around July 13. Liu Gui-Jun and Liu En-Shan (Liu and Liu, 2002) detailed their work in an internal report titled *Preliminary Report on Control of EAB*, an internal report for Ornamental Tree Management of the Guangang District, Tianjin City.

4 EAB Distribution and Damage

We investigated EAB distribution and damage both through literature and field surveys. The field surveys were focused on *Fraxinus mandshurica*, *F. rhynchophylla*, and *F. chinensis* in natural forests, plantations, and city recreation areas in Heilongjiang, Liaoning, Shandong, and Tianjin. The field surveys were conducted from June to August in Heilongjiang, and in September in the other provinces and cities because it was easy to observe the older instar larvae and damage during these periods. The surveys focused on weakened and dying trees based on the characteristics of EAB damage. If EAB emergence holes were detected (Pl. I : 2), tree bark was peeled back to check the extent of tree damage.

4.1 Literature review

EAB distribution includes Heilongjiang, Jilin, Liaoning, and Shandong provinces in China, Mongolia, the Korean Peninsula, and Japan (Yu, 1992). Shao (1996) mentions EAB occurrence in Heilongjiang and Liaoning provinces. Besides Shandong and Liaoning, Hebei and Inner Mongolia also were listed by Hou (1993). It is indicated in *Agricultural Insects of China* (Hou, 1986) that EAB occurs in Heilongjiang, Jilin, Liaoning, Hebei, Shandong and Inner Mongolia in China, Mongolia, the Korean Peninsula, and Japan.

General investigation and study on horticultural plant pests and diseases and their natural enemies in China, including those in plant quarantine (Shanghai Horticultural Institute, 1987), showed EAB distribution in 43 cities, including Dalian, Shenyang and Harbin. EAB was also found in Shenyang and Tianjin by Liu Yi-Guo (1966), Liu Hai-Qin and others (1996), and Liu Gui-Jun and Liu En-Shang (2002).

4.2 Field survey

4.2.1 EAB in China: Field surveys were conducted in the city of Tianjin and in Heilongjiang, Liaoning, and Shandong provinces, guided by available literature. Field surveys in Heilongjiang were conducted during June and July 2003 in plantations or natural forests of *F. mandshurica* in Mudangjiang, Yichun and Harbin area. There were very limited EAB occurrences in these areas, and a few EAB adults were found only in Maoershan Log Yard (Figs. 1 and 2); we found larvae alive through the winter and adults in pupa cells in Harbin in June. Also, we were able to collect a few late instar EAB larvae at the Experimental Forest of the Northeast Forestry University in Harbin in August 2003.

In September 2003, we surveyed EAB in Tianjin, where it produces only one generation per year and damaged 30 percent of the trees (Pl. I : 3). In Heilongjiang, EAB produces one generation in two years on *F. velutina* (Pl. I : 4). The main parasitoid is *Spathius* sp. with an average parasitism rate of 20 percent. The planted seedlings originated in Shandong Province.

No EAB were found during field surveys in Liaoning, even though there are EAB host trees (*Fraxinus* spp.) present. However, EAB were found on trees along a county road in Liaoning in October (Gao Rui-Tong, pers. comm.). A field trip was made in September, mainly around Dongying and Binzhou, as *Fraxinus* was used extensively as ornamental trees in these regions. Although EAB adults have been collected by staff of the Provincial Forest Protection Station in Shandong, no EAB damage was found during this field survey.

During the surveys, we found two additional parasitoids; one was identified as *Xorides* (*Xorides*) *sapporensis* (Uchida) (identified by Sheng Mao-Ling) (Pl. I : 5) and the other remains unidentified (Pl. I : 6).

Based on recent inquiries and visits with various levels of staff at forest pest control stations in Hebei, Liaoning, Jilin and Xinjiang, EAB was reported to be either present or in outbreak, especially in Hebei Province. However, the recent SARS outbreak prevented travel to Hebei for confirmation. Also, there were reports of small-scale EAB occurrences or outbreaks in several locations in Liaoning, Jilin, Hebei and Xinjiang; this is typical of EAB, as it occurs on a

site-by-site or stand-by-stand basis in most cases in China. In conclusion, there are sporadic occurrences of EAB within its range in China, but a more intensive survey is needed to identify their locations. EAB distribution is similar to that of the Asian longhorned beetle, *Anoplophora glabripennis* (Motsch.). EAB can be found throughout its suspected range, but currently there are no major outbreaks (Wu Jian, pers. comm.).

4.2.2 EAB in East Asia: We asked for help from Korean and Russian colleagues regarding EAB damage. No new information was submitted as no EAB damage has been recorded since the 1970s.

5 Discussion

5.1 Distribution and hosts

EAB was mainly distributed in Harbin, Mudangjiang, Hejiang and Yichun areas of Heilongjiang Province; Changchun, Jilin, Jiaohe (Gao Changqi, pers. comm.) and Dunhua areas of Jilin Province; Shenyang, Dandong and Benxi areas of Liaoning Province; Dongying and Binzhou areas of Shandong Province; Qinhuangdao and Tangshan areas of Hebei Province (Gao Ruitong, pers. comm.); and the Tianjin area (Fig. 1). The main hosts are *F. mandshurica* and *F. rhynchophylla* in Heilongjiang and Jilin; *F. rhynchophylla*, *F. chinensis*, and *F. mandshurica* in Liaoning Province; *F. rhynchophylla*, *F. chinensis*, and *F. velutina* in Hebei and Shandong provinces, and in the Tianjin area (Yang Zhongqi provided the tree species damaged in Tianjin) (Fig. 2). The most severe damage was found in Tianjin on *F. velutina* older than six years, while in Heilongjiang, damage was found on *F. mandshurica* around 40 years old. In other areas, we know from literature that there are occurrences of EAB, but did not find any life stages of the insect or new damage. There are some reports of EAB in Jilin and Hebei provinces, where there are host trees for EAB: we can say with certainty that EAB can exist in these areas.

The host distribution map (Fig. 2) is generated based on the information on major distribution area of host tree species of *Agrilus planipennis* in *Woody Flora of China*, *Woody Flora of Heilongjiang*, *Flora of Hebei*, *Flora of Shandong*, *Flora of Shanxi*, *Guangxi Plants*, *Flora of Shaanxi*, *Flora of Hubei*, *Flora of Jiangsu*, and *Anhui Woody Plants*.

5.2 Damage

Based on our field surveys, EAB does not pose a serious threat to natural *Fraxinus* stands or plantations. EAB attacks mainly ornamental trees, such as those in the plantation in Tianjin (Pl. I : 7) and in the Experimental Forest of Northeast Forest University (Pl. I : 8). Similar conclusions can be made concerning



Fig. 1 *Agrilus planipennis* Fairmaire distribution in China

Shandong Province. Contributing factors in outbreaks may include: a) stressed trees in those stands susceptible to EAB attack, as is the case in Harbin; b) poor site conditions, as in Tianjin and Dongying of Shandong Province; both are coastal sites with alkaline soil. The soil composition in the latter was amended with fresh soil from other areas in Dongying, which resulted in a very healthy growth of *Fraxinus velutina*, with 12-year-old trees having a diameter at breast-height (DBH) of 15 cm and no evidence of EAB. Tianjin suffered heavy EAB attack even though the seedlings transplants came from Shandong. According to *Flora of Hebei* (He, 1986) and *Flora of Shandong* (Chen, 1990), both *F. velutina* and *F. velutina* Torr. var. *toumeyi* (Britt) Rehd. were imported from the United States to Tianjin in 1952 and to the Beijing Botanical Garden in 1956. The species in Tianjin were widely planted as ornamental trees in the city, planted along the seashore, and on saline-alkaline soil in Jinan and western and northern Shandong Province. *F. americana*, *F. chinensis*, *F. pennsylvanica*, and *F. pennsylvanica* var. *lanceolata* are the major urban ornamental species in Tianjin and Shandong.

The outbreak of EAB during the 1960s occurred mainly on *Fraxinus americana*, and most trees were

removed. This may explain why no EAB was found in the Shenyang area. The plantation of *F. chinensis* was adjacent to a *F. americana* plantation at the Harbin Experimental Forest of Northeast Forestry University, which suffered attack from EAB. *Fraxinus americana* was considered as two species with one variety, that is, *F. americana*, *F. pennsylvanica* Marsh, and *F. pennsylvanica* var. *lanceolata* Sarg. It is known that *F. pennsylvanica* var. *lanceolata* Sarg exists in Heilongjiang, but the species status in Shenyang is unknown.

5.3 Suggestions for future work

(1) Differences in EAB development rates need to be studied. EAB has one generation every two years on host *F. mandshurica* in Heilongjiang, while it has one generation per year on *F. velutina* in Tianjin. This necessitates further study, including examination of geographic and climatic variables. Tianjin may be the best place to conduct an EAB study as EAB there is in the same latitude with EAB occurrences in the United States.

(2) Comparing morphological characteristics observed in pictures of EAB from the United States with that of EAB from China, clear differences in morphology were found; this may require additional clarification of



Fig. 2 *Agrilus planipennis* Fairmaire host tree distribution in China

their species identity.

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白蜡窄吉丁虫在中国的研究现状与分布调查

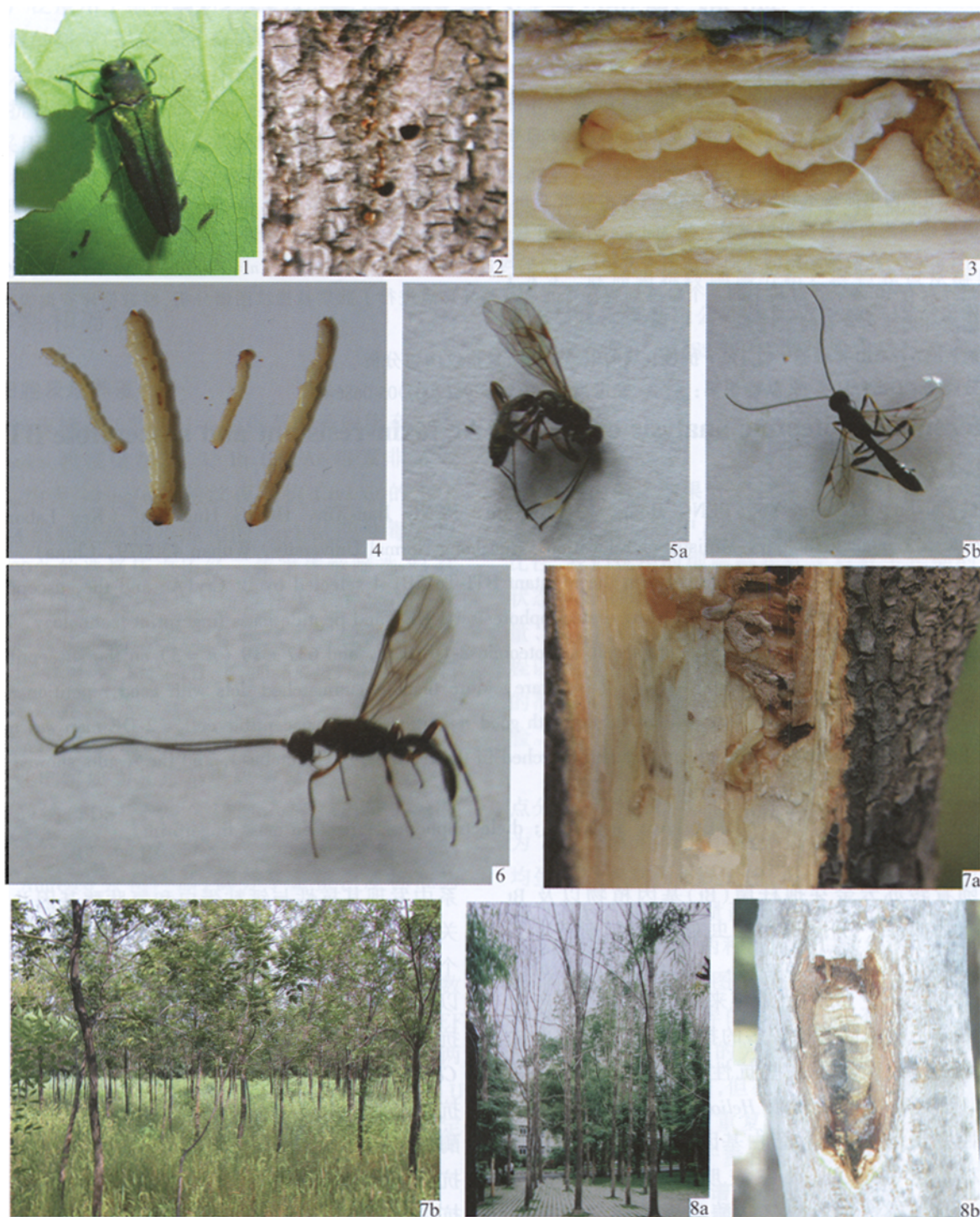
魏霞¹, Dick REARDON², 吴云², 孙江华³

(1. 黑龙江省森保所, 哈尔滨 150040; 2. 美国林务局森林保健中心;
3. 中国科学院动物研究所, 农业虫害鼠害综合治理研究国家重点实验室, 北京 100080)

摘要: 2002 年在美国密执安州发现了一重大外来入侵害虫, 白蜡窄吉丁 *Agrilus planipennis* Fairmaire, 由于该虫新近在美国发现, 危害白蜡树, 故英文名称为 Emerald Ash Borer (EAB)。初步分析显示, 该虫至少在 5 年前就已传入美国, 只是现在刚爆发被发现。目前该虫在美国密执安州和加拿大安大略省可致死各种大小的白蜡树。该虫在我国曾被定名为花曲柳窄吉丁 *Agrilus marcopoli* Obenberger, 为鞘翅目吉丁科。据资料报道分布于黑龙江、吉林、辽宁、山东、内蒙古和台湾等地; 在国外分布于朝鲜, 日本, 蒙古, 俄罗斯远东地区。危害木樨科栲属树木。两年一代或一年一代, 因地而已。在东北三省主要危害水曲柳和花曲柳等树木, 但不是主要害虫。天津市 1993 年在引种白蜡树上发现了白蜡窄吉丁, 1998 年严重爆发造成大面积白蜡树死亡。在亚洲的其他分布区, 该虫还危害另外一些阔叶树, 如多种蜡树、榆树等。鉴于该虫的广泛分布和寄主树种多及毁灭性危害的特点, 美国一些专家认为其潜在危害不亚于 1996 年在美国发现的光肩星天牛。因此, 美国已全面开展对该虫的研究, 包括资料收集, 风险性评估, 研究各种控制措施等。本文是中美对此虫合作研究的一部分, 旨在对该虫在我国的分布、危害、研究基础作一调查与回顾, 为下一步深入研究提供信息与参考资料。白蜡窄吉丁入侵北美再一次显示随着贸易的全球化发展, 外来入侵种问题也越来越严重。国际合作共同开展研究是控制入侵种的重要举措之一。

关键词: 白蜡窄吉丁; 白蜡树; 分布; 调查; 外来种

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Explanation of Plate I

1. Emerald ash borer adult; 2. EAB adult emergence holes; 3. Larva of *Agrilus planipennis* (one generation per year on host *Fraxinus velutina*) in Tianjin in August, 2003; 4. Larvae of *Agrilus planipennis* (one generation in two years on *Fraxinus mandshurica*) in Heilongjiang in August, 2003; 5. *Xorides* (*Xorides*) *sapporensis* (Uchida), having one generation every two years on host *Fraxinus mandshurica* in Heilongjiang in August 2003; 6. Another unidentified parasitic wasp with different antennae; 7. EAB damage in *Fraxinus velutina* plantation in Tianjin; 8. EAB damage in *Fraxinus mandshurica* plantation in Heilongjiang Province.